*Indian J. Phys.* 50, 846–848 (1976)

# Efficiency of F-center formation in pure and thallium activated KCl crystals by electron irradiation.

J Mukherjee, K. Goswmi, S Choudhuri and A. Choudhury

*Department of Physics, Jadavpur University, Calcutta* 700032

(*Received* 24 *March* 1976)

The efficiency of $F$ centre formation was determined for pure and Tl activated KCl crystals along the <100> and <110> directions The observed efficiency values were found to be higher in case of Tl activated KCl, but the measured depth of electron penetration had been longer in pure KCl crystals

## 1. Introduction

Numerous evidences are available on the mechanism of the defect formation by irradiating with X-rays or by any other ionising radiation (Seitz 1954, Compton & Schulman 1962). Investigations were made on the efficiency of formation of of $F$-centers in alkali halide crystals (Rabin *et al* 1960, Ritz 1964, Hirai 1972) but no report on the dependence of $F$-center production efficiency on the crystallographic orientation is available in the literature Moreover, the incorporation of foreign impurities such as Tl in KCl is expected to have an influence on the efficiency of $F$-center formation But so far, a limited attention (Pooley 1966, Butterworth *et al* 1970) has been drawn on such type ofstudies, particularly in KCl Tl crystals under electron irradiation An investigation on this may help to get a deeper insight into the mechanism of absorption and emission of light by KCl - Tl phosphors

Thin flakes of KCl<100>, KCl<119>, KCl . Tl<100> and KCl Tl<110> were used for the present investigation The absorption spectrum of KCl · Tl (0.01 At%) was obtained with the help of a Beckmann Spectrophotometer Only one peak lying at 247 m$\mu$ was detected, but the other possible absorption peak at 196 m$\mu$ could not be observed with the same instrument. The emission spectrum peaking at 470 m$\mu$ for KCl : Tl under electron irradiation was obtained The detection of other allowed emission band peaking at 305 m$\mu$ was not possible because of the limitations of the glass prism monochromator used for the present work. For a pure sample of KCl, no such luminescence under electron irradiation was observed at room temperature Although the 470 m$\mu$ emission of KCl · Tl, has not been explained clearly yet some relevant explanations have been put forward by several authors (Anderson 1964, Sturge 1967, Delbecq 1966). According to a recent communication (Ranfagni 1972), the 470 m$\mu$ emission in KCl : Tl is due to single $Tl^+$ center.

The crystals were irradiated with electrons in the energy range between 40 and 60 KeV at room temperature. *F*-centers were produced over the surface of the samples. The time of irradiation and the beam current were adjusted so as to ensure the formation of late stage coloration well below the saturation limit. The measurement of *F* absorption was carried out in a dark ambient using a RCA IP 21 photomultiplier with the conventional electronic circuits. F absorption bands were recorded for all the specimens under investigation (not shown). The efficiency of formation of *F*-center was calculated using the relation, $\eta = n_e \times E/n_F$ keV/centre. Where, $n_e$, $E$, $nF$ represent the number of incident electrons per cm$^2$ at an energy $E$, and the number of *F*-centers produced per cm$^2$. The results are shown in the given table 1.

Table 1. Efficiency values for KCl and KCl.Tl along <100> and <110> directions under electron irradiation at room temperature

| Sample | Energy of incident electron in Kev | No. of incident electrons per cm$^2$ along | | No. of *F*-centers per cm$^2$ along | | Efficiency $\eta = \frac{n_e \times E}{n_F}$ measured in KeV per center along | |
|---|---|---|---|---|---|---|---|
| | | <100> | <110> | <100> | <110> | <100> | <110> |
| | 40 | $1.06 \times 10^{14}$ | $1.17 \times 10^{14}$ | $1.77 \times 10^{15}$ | $1.41 \times 10^{15}$ | 2.4 | 3.30 |
| | 50 | $1.26 \times 10^{14}$ | $7.68 < 10^{13}$ | $2.31 \times 10^{15}$ | $1.24 \times 10^{15}$ | 2.7 | 3.09 |
| | 60 | $1.49 \times 10^{14}$ | $8.02 \times 10^{13}$ | $2.99 \times 10^{15}$ | $1.56 \times 10^{15}$ | 3.0 | 3.08 |
| | 40 | $1.40 \times 10^{14}$ | $1.46 \times 10^{14}$ | $5.20 \times 10^{14}$ | $5.24 \times 10^{14}$ | 10.8 | 11.40 |
| KCl:Tl | 50 | $1.30 \times 10^{14}$ | $1.74 \times 10^{14}$ | $6.00 \times 10^{24}$ | $6.72 \times 10^{14}$ | 10.8 | 12.60 |
| | 60 | $1.39 \times 10^{14}$ | $1.40 \times 10^{14}$ | $7.12 \times 10^{14}$ | $7.03 \times 10^{14}$ | 11.7 | 11.90 |

Further the depth of electron penetration was measured by observing the gradual decrease of optical density (due to coloration) on successive removal of surface layers of the specimen. The removal of surface layers was done by wet cut process. The depth of electron penetration was measured for various electron energies in pure KCl and Tl activated KCl. The results are shown in table 2.

Table 2. Electron energy versus the depth of electron penetration at at room temperature

| Energy in KeV | Depth of electron penetration in micron along | |
|---|---|---|
| | KCl <100> | KCl:Tl <100> |
| 40 | 15 | 10 |
| 50 | 20 | 13 |
| 60 | 26 | 15 |

## 5. Discussion

The results as given in table 1 show that the efficiency values for pure KCl under electron irradiation do not ppreciably change with the change of energy of the incident electrons. Practically no appreciable difference is found in the efficiency values for pure KCl<100> and KCl<110> crystals and a similar trend of result is found for Tl activated KCl crystals In the present case, the fluctuations of the results are found to be of the similar order as developed in other works (Hermann *et al* 1970) But there is a marked difference in the measured $F$-center efficiency ($\eta$) values between pure and activated samples of KCl. The increase of efficiency values due to the presence of Tl in KCl gives rise to lowering of $F$-center production rate, but at the same time it produces luminescence which is almost absent in pure KCl crystal

The diminution of coloration (table 1) in KCl Tl crystals may be attributed to the suppression of late stage coloration by the $Tl^+$ ions It may be seen (table 2) that the depth of electron penetration for a particular energy is depth of electron penetration for a particular energy is longer in pure KCl than in KC. · Tl The electron energy loss ($-dE/dx$) in pure KCl is primarily due to production of color centers. But the energy loss in Tl-activated KCl is due to color center formation as well as due to luminescence emission. An estimate of the energy loss due to $F$-center formation in KCl crystal may be made from the data given in table 2. But in case of KCl : Tl crystal, the energy loss can not be determined for want of relevant data available on the eargy loss associated with the process of luminescence. Perhaps, this may be achieved by determining the quantum efficiency for KCl · Tl samples under electron-irradiation

## References

Anderson J. E. A. 1964 *Phys, Stat, Solidi* **7**, 21.
Butterworth J. S., Esser P. D. & Levy P. W. 1970 *Phys. Rev.* B, **2**, 8, 3350.
Compton W. D. & Schulmna J. H 1962 *Color centers in Solids*, McMillan, New York.
Delbecq C. J., Ghosh A K. & Yuster R. H. 1966 *Phys. Rev* **151**, 2, 599.
Hermann F. & Pinard P. 1970 *J. Phys* **c. 3**, 1037
Hirai M. 1972 *Solid State Communications* **10**, 493
Pooley D. 1966 *Proc. Phys. Soc.*, **89**, 723.
Rabin H. & Klick C. C. 1960 *Phys Rev.* **117**, 4, 1005
Rangfagni A. Pazzi G.P., Fabeni P , Villani G. & Fontanna M. P. 1972 *Phys Rev. Letters* **28**, 1035
Ritz V H. 1964 *Phys. Rev.* **133A**, 1452
Seitz F. 1954 *Rev Mod. Phys.* **26**, 7.
Sturge M. D. 1967 *Solid State Phys* **20**, 91